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FLUCTUATION INDUCED CONDUCTIVITY STUDIES OF 100 MeV OXYGEN ION IRRADIATED Pb DOPED Bi-2223 SUPERCONDUCTORS

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We report on 100 MeV oxygen ion irradiation in Pb doped Bi-2223 superconductors. Resistivity measurements reveal that both grains as well as the grain boundaries are affected by such irradiation. An analysis of the excess conductivity has been made within the framework of Aslamazov-Larkin (AL) and Lawrence-Doniach (LD) theories. A 2D to 3D transition is observed with increasing fluences. The coherence length and the Josephson coupling has been estimated from LD theory.

1. INTRODUCTION

The fluctuations in the order parameter, ψ, of the superconducting grains, give rise to excess conductivity above and below the transition temperature (T_c). This excess conductivity or paraconductivity causes dimensional crossover and is associated with strong anisotropy and interlayer coupling in high temperature superconductors (HTS). Irradiation by swift heavy ions (SHI) introduces atomic scale defects in these HTS introduces atomic scale defects in these HTS, leading to fluctuations of the order parameter in them. Using Aslamazov-Larkin (AL) theory [1] excess conductivity $\Delta\sigma$ is defined as $\Delta\sigma = A\varepsilon^{-\lambda}$ where $A=e^2/32\eta\ \xi(0)$ and $\lambda = 0.5$ in 3D and $A = e^2/16\eta d$ with $\lambda = 1$ in 2D. ε is the reduced temperature defined as $(T-T_c^{mf})/T_c^{mf}$, $\xi(0)$ is the coherence length at T=0 and d is the effective separation of CuO_2 layers. T_c^{mf} is defined by the inflection point of the $d\rho/dT$ versus temperature plot. The dimension of the system is then calculated using the relation $\lambda = 2-D/2$. Lawrence and Doniach (LD) [2] modified the AL theory by introducing a Josephson coupling term J in the definition of excess conductivity as

$\Delta\sigma_{2D} = e^2/16\eta d\ \varepsilon^{-1}\ [1+\{2\xi_c(0)/d\}^2]^{-1/2}$ where the coupling strength J is defined as $J=(\xi_c(0)/d)^2$. In this work, an analysis of the excess conductivity on the irradiated and unirradiated Pb doped Bi-2223 HTS has been done within the framework of the AL and LD theory in the temperature range T_c to $2T_c^{mf}$.

2. EXPERIMENTAL DETAILS

Solid state reaction route was employed to prepare monophasic Pb-doped Bi-2223 compounds [3]. Resistivity measurements were done using standard probe technique. The samples have been irradiated at fluences of 10^{13} ions/cm^2, 3×10^{13} ions/cm^2, 5×10^{13} ions/cm^2 and 7×10^{13} ions/cm^2 at normal incidence with 100 MeV oxygen using the 15 UD Pelletron tandem accelerator at Nuclear Science Centre, New Delhi.

3. RESULTS AND DISCUSSION

The variation of the resistivity of the irradiated samples with temperature at various fluences have been shown in Fig.1. An initial decrease of resistivity was observed at lower fluences but at higher fluences the RT resistivity was found to increase. The values of $T_c(0)$, T_c(onset) and ΔT_c are shown in Table 1. AL theory has been used to fit the fluctuation induced conductivity of the unirradiated and irradiated samples. The parameters extracted from this analysis have been tabulated in Table 1. With increasing fluence, a dimensional crossover from 2D to 3D is observed accompanied by a decrease of $\xi(0)$ and Josephson coupling J between CuO_2 planes. This arises due to irradiation induced disorder setting up in the CuO_2 planes as well as the gradual build up of the Bi-2212 phase [3]. The above findings are in good agreement with reported values [4].

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Table 1
Various parameters characteristic of irradiated and unirradiated Bi(Pb)-2223 samples.

Fluence (ions/cm^2)	T_{c0} (K)	T_{conset}(K)	ΔT_c(K)	T_c^{mf} (K)	T_0 (K)	λ	Dimension	J	$\xi_c(0)$Å
Unirradiated	107	111	4	110.4	114.1	1.4	2D	0.0166	1.692
10^{13}	107	113	6	110.2	113.4	0.73	2D	0.0143	1.568
$3x10^{13}$	107	113	6	110	111.6	0.21		0.0069	1.096
						1.05	2D		
$5x10^{13}$	107	113	6	109.4	110.6	0.48	3D	0.0055	0.968
						1.60	2D		
$7x10^{13}$	103	113	10	107.4	111.9	0.38	3D	0.0208	1.893
						0.54	3D		

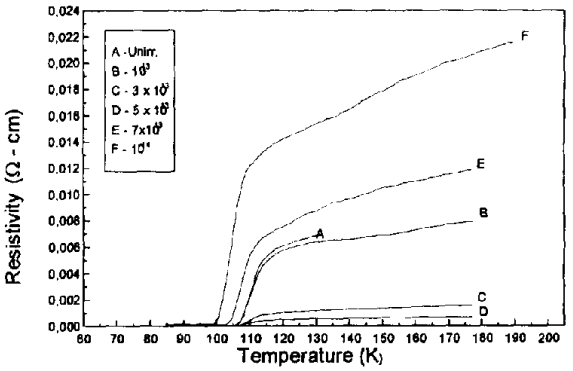

Fig.1: Resistivity plots of unirradiated and irradiated Bi(Pb)- 2223erconductors

4. CONCLUSIONS

We have investigated the effect of SHI radiation on the transport properties and on the granular behaviour of Pb doped Bi-2223 superconductors. The damage done to both grains as well as grain boundaries as a result of irradiation was manifested in the change of T_c (0) and increasing ΔT_c. An analysis of the excess conductivity of irradiated Pb doped Bi-2223 superconductors done within the framework of AL and LD theory shows that irradiation induced disorder leads to the formation of the lower phase which exhibits a crossover from 2D to 3D behaviour at higher fluence. The decrease of J indicates that the effective distance between the CuO_2 planes changes as a result of displacement per atom caused due to SHI irradiation. The decrease of the $\xi_c(0)$ values indicates that the sample goes to a more disordered state with increasing radiation fluence.

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